

COATED SUNGLASS LENS

The present invention relates to optical articles bearing a light absorbing coating.

5 The optical articles according to the present invention are preferably employed in the preparation of articles such as optical lenses, including spectacle lenses, including sunglass lenses, visors, shields, glass sheets, protective screens, and the like.

Sunglasses generally serve to attenuate transmitted light, but aside from the level of light transmittance, there are other features that distinguish different
10 sunglass lenses, such as material, transmitted colour, scratch resistance, reduction of side glare, ultra-violet transmittance, cosmetic appearance etc. Coatings may be applied to enhance the performance of sunglass lenses. Such coatings might include scratch resistant coatings, hydrophobic coatings for easier cleaning, anti-reflection coatings on the concave surface for reducing side glare or
15 "mirror" (or "interference") coatings for producing fashionable lens colours. General purpose sunglass lenses should meet certain standard specifications, including luminous transmittance, traffic signal recognition and UV transmittance (e.g. ANSI Z80.1-1995).

In addition to their performance characteristics, sunglass lenses should be
20 simple and economical to produce in a reliable manner.

As is known in the prior art, the preferred method for producing sunglass lenses is dependent on the material involved. In all cases a light-attenuating material is either incorporated into the substrate material or applied over its surface in a process known as "tinting". For example, glass lenses are often tinted
25 by introducing coloured additives to the molten glass, and similarly polycarbonate lenses are injection-moulded from pre-coloured plastic granules. A disadvantage associated with this method of production is that for economical reasons, very large batches of coloured raw material must be purchased, limiting flexibility in the range of tint colours that can be offered in the sunglass lens product. Moreover,

prescription sunglass lenses with highly varying thickness will also exhibit non-uniform transmittance when coloured in this way. Hard resin lenses (another commonly used ophthalmic plastic) are usually dipped in a hot, liquid dye which is imbibed into the plastic. This process also has disadvantages, such as difficulty in achieving tint uniformity, poor colour reproducibility and its requirement that if the lens has a scratch resistant coating, it must be semi-permeable to allow imbibition of the dye molecules, hence compromising the scratch resistance. If a reflective mirror coating is desired, the tinted substrate is then cleaned and coated in an evaporative box coater. Such multi-stage processes are both time-consuming and expensive.

One proposal in the prior art to overcome some of the problems associated with lens tinting is to apply the light absorbing material as a thin film on an essentially transparent substrate. United States Patent No. 5,770,259 (Parker and Soane) describes a method for tinting sunglass lenses using a curable primer containing a tinting agent. Vacuum deposition allows the light absorbing coating to be applied in a relatively fast, clean, flexible and controllable manner. United States Patent No. 5,729,323 (Arden and Cumbo) describes a sunglass formed by depositing a multi-layer light absorbing coating containing TiO_x ($x=0.2-1.5$) on the concave surface of the substrate. The coating is anti-reflective from the wearer's side of the lens. United States Patent No. 3679291 (Apfel and Gelber) describes a metal-dielectric multi-layer coating that is light absorbing and has an asymmetric reflectance, being anti-reflective from one side and with strong colour on the other side.

Another time-consuming step in the production of corrective sunglass lenses is the surfacing of the lenses. Corrective (or prescription) sunglass lenses are often dispensed using "semi-finished blanks" - lenses that have a pre-moulded front surface and a back surface that must be ground and polished to satisfy the individual wearer's corrective prescription. For plastic lenses in particular, tinting and the deposition of further lens coatings must be performed after surfacing the lens, resulting in a long and labour-intensive process to produce and deliver the sunglass lenses. One means to simplify and accelerate lens delivery is to employ

a wafer lamination scheme, where front and back lens wafers spanning a large range of optical powers are simply glued together to produce a lens of virtually any desired prescription. Instead of maintaining a complex optical grinding and polishing workshop, the optical dispenser need only maintain an inventory of
5 wafers and a lamination unit. The use of fast curing glues allows lenses to be produced in only minutes. Additional performance enhancing coatings may be applied to the wafers at the factory, so that the dispenser may provide the desired product features immediately, simply by selecting the appropriate wafers from his inventory.

10 For laminated lens wafer systems, for example of the Sola International Matrix[®]-type, liquid bath tinting is not a desired option - it is a low yield process involving significant handling and possible distortion of fragile wafers. Such tinted lenses may also exhibit poor abrasion and scratch resistance and variable depth of colour.

15 Moreover, for sunglass lenses in particular, it would be a significant advance in the art if, in addition, reflection of visible light at the concave (or rear) lens surface could be kept sufficiently low to avoid glare from incident light at the concave surface.

Accordingly, it is an object of the present invention to overcome, or at
20 least alleviate, one or more of the difficulties or deficiencies related to the prior art.

Accordingly, in a first aspect of the present invention there is provided an optical lens including

- an optically clear lens element; and
- a light absorbing coating on the front surface of the lens that
25 attenuates transmitted light;
 - has a coloured or colourless reflection as seen from the front of the sunglass lens; and
 - is anti-reflective as seen from the eye side of the lens.

It will be understood that, in accordance with the present invention, one or

more surfaces of an optical lens is coated with a light absorbing coating. This light absorbing coating may be applied to either the outside surface of the lens or an inside surface of a lens wafer (where it is protected from scratching once the wafers are laminated) as discussed below. The light absorbing coating may
5 preferably serve three purposes at once - to attenuate transmitted light, effectively providing the sunglass "tint," to produce a reflected colour that is of pleasing appearance and to reduce or minimise back reflections seen by a wearer of the sunglass lenses.

In a preferred form, the light absorbing coating may function as a mirror
10 coating. Thus, the tinting and mirror coating processes may be combined into one with this coating.

Further the deposited coating may exhibit much improved adhesion and thus improved abrasion resistance.

In a further aspect of the present invention there is provided an optical
15 lens including
an optically clear lens element; and
a light absorbing coating on the rear surface of the lens, such that the light absorbing coating
attenuates transmitted light;
20 has a coloured or colourless reflection as seen from the front of the sunglass lens; and
is anti-reflective as seen from the eye side of the lens.

Preferably the light absorbing coating is an asymmetric reflectance, light absorbing coating including a plurality of overlapping light absorbing and generally
25 transparent layers, and wherein the thickness and/or number of the respective layers are selected to provide an anti-reflective effect on the eye side of the optical lens and a desired colour on the other side of the lens.

By the term "coloured or colourless reflection", as used herein, we mean that light from a white fluorescent source is reflected from the surface of the

optical lens to an observer such that the reflected light is coloured or white respectively.

By the term "asymmetric reflectance", as used herein, we mean that the multi-layer coating renders the lens anti-reflective when viewed from one side of the coating and exhibits a selected colour or colourless reflection when viewed from the other side.

The optically clear lens element may be a sunglass lens, ophthalmic lens element, visor or the like. A sunglass lens is preferred.

By the term "ophthalmic lens element", as used herein, we mean all forms of individual refractive optical bodies employed in the ophthalmic arts, including, but not limited to, lenses, lens wafers and semi-finished lens blanks requiring further finishing to a particular patient's prescription.

Where the optically clear lens element is an ophthalmic lens element, the ophthalmic lenses may be formed from a variety of different lens materials, and particularly from a number of different polymeric plastic resins. A common ophthalmic lens material is diethylene glycol bis (allyl carbonate). Lens materials with higher refractive indices are now growing in popularity. One such material is a CR39 (PPG Industries). Other high index lens materials are based on acrylic or allylic versions of bisphenols or allyl phthalates and the like. Other examples of lens materials that may be suitable for use with the invention include other acrylics, other allylics, styrenics, polycarbonates, vinylics, polyesters and the like.

The light absorbing coating may be formed from overlapping light absorbing and generally transparent layers, as discussed above. Desirably the light absorbing coating is formed from alternating transparent and absorbing layers.

The number and/or thickness of the light absorbing and generally transparent layers may be selected to provide an eye side anti-reflective coating utilising suitable computer software.

The combination of light absorbing and transparent layers may be selected to provide a bright, coloured reflection when viewed from the front of the lens at the same time. A mirror type coating may be produced.

The transparent layers may be formed from any suitable optically clear material. The transparent layers may be formed of a dielectric material. Preferably the dielectric layers may be formed from metal oxides, fluorides or nitrides. Metal oxides which may be used for forming transparent layers include one or more of SiO, SiO₂, ZrO₂, Al₂O₃, TiO, TiO₂, Ti₂O₃, Y₂O₃, Yb₂O₃, MgO, Ta₂O₅, CeO₂ and HfO₂. Fluorides which may be used include one or more of MgF₂, AlF₃, BaF₂, CaF₂, Na₃AlF₆, Ta₂O₅, and Na₅Al₃Fl₁₄. Suitable nitrides include Si₃N₄ and AlN.

A silica (SiO₂) material is preferred.

In a particularly preferred embodiment, the first deposited layer may be a silica layer followed by alternating light absorbing and generally transparent, preferably silica, layers. The transparent dielectric layers may be substantially thicker than the light absorbing or metallic layers. The first layer may be of approximately 10 to 75 nm, preferably approximately 25 to 60 nm. This first layer may provide significant improvement in the abrasion resistance of the multi-layer coating.

The generally transparent layers within the body of the light absorbing coating may be relatively thick. The thicknesses may be such as to generate interference effects which substantially cancel out internal reflections. Thicknesses of for example from approximately 20 nm to 100 nm, preferably approximately 25 nm to 85 nm may be used.

The light absorbing layers of the light absorbing coating may be formed from any suitable material. Metals, metal oxides or nitrides may be used.

Desirably a metallic layer may be selected to provide a generally neutral, e.g. grey transmission. Accordingly a silver-coloured metal, e.g. Niobium (Nb), Chromium (Cr), Tungsten (W), Tantalum (Ta), Tin (Sn), Palladium (Pd), Nickel (Ni)

or Titanium (Ti) or mixtures thereof may be used.

The thickness of the light absorbing layers is such as to attenuate transmitted light. The light absorbing or metallic layers may generally be of a substantially reduced thickness relative to the transparent or dielectric layers. For
5 example if the material used is Niobium, the light absorbing layers may be from approximately 1 nm to 10 nm, preferably approximately 2 nm to 5 nm in thickness.

In a preferred form, the light absorbing coating may include a total of 4 to 12 alternating light absorbing-generally transparent layers, preferably 6 to 8 alternating layers. An additional primer layer may be included, as discussed
10 above.

The resultant coating may exhibit a silver (colourless) mirror-type appearance. Alternatively the light absorbing coating may be modified to produce a different colour coating. For example a metallic oxide, e.g. silica or niobium oxide coating may be applied. A combination of dielectric top coatings may be
15 applied. A silica top coat may be added to modify colour and additionally enhance abrasion resistance.

Accordingly in a preferred form, the light absorbing coating includes alternating layers of a dielectric material and a metallic material;

the dielectric material being selected from one or more of SiO, SiO₂, ZrO₂,
20 Al₂O₃, TiO, TiO₂, Ti₂O₃, Y₂O₃, Yb₂O₃, MgO, Ta₂O₅, CeO₂ and HfO₂, MgF₂, AlF₃, BaF₂, CaF₂, Na₃AlF₆, Ta₂O₅ and Na₅Al₃Fl₁₄; and Si₃N₄ and AlN; and

the metallic material is selected from the metals, metal oxides or nitrides of one or more of Niobium (Nb), Chromium (Cr), Tungsten (W), Tantalum (Ta), Tin (Sn), Palladium (Pd), Nickel (Ni) or Titanium (Ti).

25 More preferably the light absorbing coating includes alternating layers of silica (SiO₂) and chromium metal.

More preferably the light absorbing coating includes an additional titanium dioxide layer or layers of such a thickness to provide a desired colour to the

optical lens.

Alternatively, the light absorbing coating includes alternating layers of silica and niobium metal.

Preferably the light absorbing coating includes an additional niobium
5 oxide (Nb_2O_5) and/or silica (SiO_2) layer of such thicknesses to provide a desired colour to the optical lens.

In a still further preferred embodiment the light absorbing coating further includes compatible dielectric layers of suitable thickness to provide a desired colour to the optical lens.

10 The optical lens may further include one or more additional coatings.

Accordingly in a further aspect of the present invention there is provided a multi-coated optical lens including

an optical article; and

a light-absorbing coating deposited on at least one surface of the optically
15 clear article; the light-absorbing coating including a plurality of overlapping light absorbing and generally transparent layers, and wherein the thickness and/or number of the respective layers being selected to provide an anti-reflective effect on the eye side of the optical lens and a desired colour on the other side of the optical lens, and

20 an optically clear secondary coating which provides a desirable optical and/or mechanical property to the optical article.

The optically clear secondary coating may preferably underlay or overlay the light absorbing coating.

The secondary coating may be of any suitable type. The secondary
25 coating may be one or more of an anti-reflective, abrasion resistant, or impact-resistant coating. An abrasion-resistant coating is preferred. The combination of an abrasion resistant coating and an anti-reflective coating is particularly

preferred.

An abrasion-resistant (hard) coating including an organosilicone resin is preferred. A typical organosilicone resin that is suitable for use in the present invention has a composition comprising one or more of the following:

- 5 1) organosilane compounds with functional and/or non-functional groups such as glycidoxypropyl trimethoxy silane;
- 2) co-reactants for functional groups of functional organosilanes, such as organic epoxies, amines, organic acids, organic anhydrides, imines, amides, ketamines, acrylics, and isocyanates; colloidal silica, sols and/or
10 metal and non-metal oxide sols; catalysts for silanol condensation, such as dibutyltin dilaurate;
- 3) solvents such as water, alcohols, and ketones;
- 4) other additives, such as fillers.

Abrasion resistant coats of acrylic, urethane, melamine, and the like may
15 also be used. These materials, however, frequently do not have the good abrasion resistant properties of organo-silicone hard coatings.

The abrasion-resistant (hard) coating may be coated by conventional methods such as dip coating, spray coating, spin coating, flow coating and the like or by newer methods such as Plasma Enhanced Chemical Vapour Deposition.
20 Coating thicknesses of between approximately 0.5 and 10 microns are preferred for abrasion and other properties.

The secondary abrasion resistant coating may be applied to the front and/or rear lens surfaces. The abrasion resistant coating may be of the type described in United States Patent 4,954,591 to the Applicants, the entire
25 disclosure of which is incorporated herein by reference.

In a preferred aspect, one or both surfaces of the optical article may be subjected to a surface treatment to improve bondability and/or compatibility of the light absorbing and/or secondary coating. The surface treatment may be selected from one or more of the group consisting of plasma discharge, corona discharge,

glow discharge, ionising radiation, UV radiation, flame treatment and laser, preferably excimer laser treatment. A plasma discharge treatment is preferred. The surface treatment, alternatively or in addition, may include incorporating another bonding layer, for example a layer including a metal or metal compound
5 selected from the group consisting of one or more of Chromium, Nickel, Tin, Palladium, Silicon, and/or oxides thereof.

The optical article may be a sunglass lens of the wrap-around or visor type, for example of the type described in International Patent Application PCT/AU97/00188 "Improved Single Vision Lens" to Applicants, the entire
10 disclosure of which is incorporated herein by reference.

In a further aspect of the present invention, there is provided a method for preparing an optical lens, which method includes providing

an optically clear lens element; and
15 a light absorbing coating on the front surface of the lens that attenuates transmitted light; has a coloured or colourless reflection as seen from the front of the sunglass lens; and is anti-reflective as seen from the eye side of the lens; and
20 depositing the light absorbing coating on a surface of the optical lens element.

According to the present invention it has been found that, following the method mentioned above, it is possible to achieve a relatively thin, light absorbing coating with consequent advantages in both optical and mechanical properties.

25 Preferably the method further includes providing
an optically clear lens element,
a light absorbing material, and
a generally transparent material;
30 depositing overlapping layers of light absorbing material and generally

transparent material on a surface of the optical lens element, the number and/or thickness of the respective layers being selected to provide a desired colour to the front surface of the optical lens and an anti-reflective effect on the eye side of the optical lens.

- 5 In a preferred aspect the light absorbing or metallic material and generally transparent or dielectric material, preferably Nb and SiO₂ or Cr and SiO₂, are deposited as alternating layers.

 The deposition step may be a vacuum deposition step. The deposition step may be conducted in a coating apparatus. A box coater or sputter coater
10 may be used.

 The light absorbing coating may preferably be formed on the surfaces of the substrate according to the process and the box coaters as described in the Italian Patent No. 1.244.374 the entire disclosure of which is incorporated herein by reference.

- 15 In accordance with said method, the various layers of the light absorbing coating may be deposited in subsequent steps utilising a vacuum evaporation technique and exposing the growing layers to a bombardment of a beam of ions of inert gas.

 Moreover, in accordance with the preferred method, the deposition of the
20 layers may be achieved at a low temperature (generally below 80°C), using an ion beam having a medium intensity (meaning the average number of ions that reach the substrate) included between approximately 30 and 100 $\mu\text{A}/\text{cm}^2$ and the energy included between approximately 50 and 100 eV.

 Preferably, the optical article is maintained at an elevated temperature
25 during the deposition of the various layers of the light absorbing coating.

 More preferably the optically clear lens element includes
a front lens wafer including

a contact surface,
a complementary back lens wafer, including
a contact surface
and the overlapping layers of light absorbing material and generally
5 transparent material are deposited on a surface of the front and/or complementary
back lens wafer.

A laminate adhesive may be applied to one or both contact surfaces, the
front lens wafer and back lens wafer being brought into contact and the laminate
so formed being subjected to a curing step to form a laminate optical lens.

10 In a further preferred aspect of the present invention, there is provided an
optical lens element including
a lens wafer having
a first lens surface; and
a second lens surface,
15 the first or second surface having deposited thereon
a light absorbing coating that
attenuates transmitted light;
has a coloured or colourless reflection as seen from the front of the
sunglass lens; and
20 is anti-reflective as seen from the eye side of the lens.

Preferably the light absorbing coating is an asymmetric reflectance light
absorbing coating including a plurality of overlapping light absorbing and generally
transparent layers; the thickness and/or number of the respective layers being
selected to provide a desired colour to the optical lens element and an anti-
25 reflective effect on the eye side of the lens element after lamination of the lens
wafer.

The coated lens wafer may be a front surface wafer or a rear surface
wafer. Where the coated lens wafer is a front surface wafer the light absorbing
coating may be deposited on the first (front) or second (rear) lens surface thereof.

Where the coated lens wafer is a rear surface wafer, the light absorbing coating is preferably deposited on the first (front) surface thereof.

Accordingly in a still further aspect of the present invention, there is provided a laminate optical lens including

- 5 a front lens wafer including
 - a contact surface;
 - a complementary back lens wafer including
 - a contact surface; and
 - a light absorbing coating deposited on a contact surface, which light
- 10 absorbing coating
 - attenuates transmitted light;
 - has a coloured or colourless reflection as seen from the front of the sunglass lens; and
 - is anti-reflective as seen from the eye side of the lens.

- 15 Preferably the light absorbing coating includes a plurality of overlapping light absorbing and generally transparent layers; the thickness and/or number of the respective layers being selected to provide a desired colour to the laminate optical lens and an anti-reflective effect on the eye side of the laminate optical lens, as discussed above.

- 20 It will be understood that, in this embodiment, in addition to the advantages of the present invention described above, the light absorbing coating provided may be protected by the optical lens wafers themselves and is thus virtually indestructible.

- 25 In addition, abrasion resistant and like coatings of the type described above may be applied to the external surfaces of the laminate optical article.

The laminate optical article may be fabricated in a manner similar to that described in International Patent Application PCT/AU96/00805, "Laminate Article", to Applicants, the entire disclosure of which is incorporated herein by reference.

Where the light absorbing coating is applied inside the laminate, particularly for hard resin lenses, because the lens is not tinted in a liquid bath, the scratch resistant coating applied to the exterior of the wafers does not need to be semi-permeable (to allow passage of the tint molecules through to the substrate).

5 Therefore, the most durable, non-tintable scratch resistant coatings may be applied and the final product is extremely durable. The light absorbing coating is protected inside the laminate and cannot be scratched. Because the light absorbing coating is located approximately in the centre of the laminate, when the lens is edged for mounting into spectacle frames, the edges appear "dark" and it is

10 difficult to discern that the "tinted" appearance of the lens is due only to a very thin coating. Finally, as can be seen in Figure 2 below, there is a double reflection from the front of the lens, one "white" reflection from the front of the front wafer and one coloured reflection from the light absorbing coating inside the laminate. If the front wafer is thin and has no optical power, the two reflections overlay one

15 another and only a single reflection is observed. However, if the front wafer is thick and has surfaces of different curvature, then the two front reflections become apparent. A quite pleasing "glossy" effect is obtained.

Before the lens wafers of the laminate lens are bonded, they may be too thin to meet United States F.D.A impact requirements. A sunglass wearer may be

20 put at risk if he wears sunglasses which have been made using only the front or back wafer of the laminate. It may be necessary for a prescription sunglass manufacturer to ensure that non-laminated wafers are not mounted in sunglass frames for general use. One way to achieve this end is to ensure that the lens wafers are visibly identified with a warning symbol as unsuitable for use, in such a

25 way that after the wafers are laminated, the warning is no longer visible. For example, the current Matrix[®] lens lamination system includes a warning symbol in the centre of the contact surface of each lens wafer - a roughened area of the surface that causes unacceptable disturbance of the wearer's vision and thus effectively prevents use of non-laminated wafers alone in spectacles. However,

30 when the wafers are laminated using an adhesive of refractive index suitably matched to the lens material, the interface corresponding to the roughened surfaces optically disappears, so that the warning symbol is no longer visible.

If the light absorbing coating is applied over such a roughened contact surface, it is visible from the front of the wafer. It is also visible from the back of the wafer, because until the wafer is laminated, it is exposed to air rather than another lens wafer, so the coating does not perform antireflectively as designed.

- 5 The roughened surface causes substantial light scattering toward the wearer and significantly disturbs his vision, so much so that the front lens wafer would not conceivably be used in a non-laminated state as a sunglass lens. After lamination, the coating is antireflective when viewed from the rear - light scattering from the roughened surface is very weak and so the roughened area is invisible to
- 10 the wearer. If the contact surface of the lens wafer is roughened in a cosmetically pleasing fashion, then not only are non laminated lens wafers clearly identified, but after the coated wafers are laminated, a logo that is visible from the front of the lens but yet does not disturb the wearer's vision results.

- Accordingly, in a preferred embodiment of the present invention a contact
- 15 surface of the front and/or back lens wafer bears a mark thereon, the mark being substantially visible from both sides of the wafer before lamination, but which becomes substantially invisible from the eye side of the finished laminate lens. Preferably the mark on the contact surface is visible from the front of the laminated lens.

- 20 In an alternative embodiment where the mark on the contact surface is not visible from the front of the final laminated lens, the light absorbing coating includes a silica top layer, the silica top layer bearing a mark visible prior to lamination, as discussed above.

- Preferably the visible mark is rendered substantially invisible when the lens
- 25 wafer is contacted with a laminate adhesive having a refractive index approximately equal to that of the silica layer.

- The light absorbing coating may for example be purposefully constructed to have a top layer of silica, which has a refractive index of approximately $n=1.47$. An excimer laser or other etching technique can be applied to remove (or merely
- 30 reduce the thickness of) the top silica layer of part of the coating in the form of a

warning label, which will be very visible before the wafer is laminated. However, after lamination, glue will fill the depressions caused by the etching, and because the glue can be chosen to have a refractive index very close to that of silica, the etched markings will have no optical effect and hence disappear, making the
5 laminated lens suitable for use.

Alternatively, instead of removing part of the top silica layer, a warning label may be deposited on top of the silica layer with a suitably index-matched material, for example an adhesive or polymer material. Again, after lamination, glue will fill the void around the raised warning label, and because the glue can be chosen to
10 have a refractive index very close to that of silica and the label itself, the warning marking will have no optical effect and hence disappear, making the laminated lens suitable for use.

Further characteristics and advantages of the present invention will be apparent from the following description of drawings and examples of
15 embodiments of the present invention, given as indicative but not restrictive.

In the figures:

Figure 1 illustrates an embodiment of a sunglass lens according to the present invention with the light absorbing coating inside the laminate.

Figure 2 illustrates the attenuation of transmitted light through the
20 sunglass lens of Figure 1 from a forward light source.

Figure 3 illustrates the attenuation of reflected light from the sunglass lens of Figure 1 from side glare.

Figure 4 illustrates the transmission spectra of a "black" laminated lens (see Table 1), as compared to a typical liquid-dye tinted hard resin sunglass lens.

25 Figure 5 illustrates an embodiment of a laminated sunglass lens with semi-visible internal markings.

Figure 6 illustrates an embodiment of a sunglass lens according to the present invention with the light absorbing coating on the outside surface of the front wafer.

Figure 7 illustrates the attenuation of transmitted light through the sunglass lens of Figure 6 from a forward light source.

Figure 8 illustrates the attenuation of reflected light from the sunglass lens of Figure 6 from side glare.

Figure 9 illustrates an embodiment of a sunglass lens according to the present invention with the light absorbing coating on the outside surface of the back wafer.

Figure 10 illustrates the attenuation of transmitted light through the sunglass lens of Figure 9 from a forward light source.

Figure 11 illustrates the attenuation of reflected light from the sunglass lens of Figure 8 from side glare.

EXAMPLE 1

Light absorbing coating on the inside of a laminated lens

Figure 1 shows a preferred embodiment of a tinted optical lens according to the present invention. The front and back lens wafers are hard resin plastic wafers from a commercial ophthalmic lens system (Sola International Matrix® system). The back lens wafer is supplied with its external surface pre-coated with a scratch resistant and anti-reflective coating. The external surface of the front wafer is also treated with a scratch resistant coating. The internal surfaces of both wafers are of uncoated hard resin.

A light absorbing coating with asymmetric reflectance is applied to the interface surface of the front wafer. (It may equally well be applied to the internal

surface of the back wafer instead. Only the first case will be discussed for simplicity.) The coating is designed so that when the wafers are laminated, neutral attenuation of transmitted light, an aesthetically pleasing colour when viewed from the front of the lens and anti-reflection from the wearer-side of the lens result, as shown in Figures 2 and 3. Referring to Figure 3, it will be appreciated that possible reflections from surfaces behind the light absorbing coating do not contribute in any significant manner, because their intensity is severely reduced by the incident light having initially passed through the light absorbing coating. Such reflections are therefore not indicated in the figure.

10 The multi-layer light absorbing coatings consist of layers of absorbing materials and transparent dielectrics. The layers of absorbing material provide the attenuation of transmitted light. The degree of attenuation is controlled by adjusting the total thickness of these layers. If the absorbing material has a neutral transmission spectrum (as do many metals), the transmission of the
15 coating will also be neutral, which is highly desirable for a sunglass lens that does not distort colour vision. By appropriately selecting the thicknesses of the various layers (which today is commonly achieved with the aid of computer software packages), the reflectance of the coating may be designed to have the required properties of a pleasing colour when viewed from the front of the lens and anti-
20 reflection from the wearer side.

Table 1 lists the materials and layer thicknesses used in three differently coloured embodiments of the light absorbing coating. The coatings were deposited using a commercial evaporative box coater (Satis 1200).

TABLE 1

Layers			Thickness (nm)		
Number	Material	Primary function	Bronze	Blue	Black
Substrate					
1	Cr	Adhesion to substrate	0.5	0.5	0.5
2	TiO ₂	Front colour	37	35	20
3	SiO ₂	Front colour	9	50	20
4	TiO ₂	Front colour	88	-	20
5	Cr	Absorption	14	12	12
6	SiO ₂	Back AR	65	65	65
7	Cr	Absorption	9	9	9
8	SiO ₂	Back AR	85	85	85
9	Cr	Absorption	2.5	2.5	2.5
10	SiO ₂	Scratch resistance	5	5	5

5 Table 1. Composition of three differently coloured embodiments of the light absorbing coating as deposited inside the laminated sunglass lens.

The sequence of layers is relative to a light ray entering the front surface of the optical lens.

Table 2 shows the optical performance of the sunglass lenses in transmittance.

TABLE 2

Transmission	Bronze	Blue	Black
Luminous transmittance (%)	12.1	11.4	13.5
CIE x coordinate (illum. C)	0.36	0.38	0.37
CIE y coordinate (illum. C)	0.35	0.37	0.35
Av. UVB transmittance (%)	0	0	0
Av. UVA transmittance (%)	1.8	1.4	2.2
Red traffic signal trans. (%)	16.3	16.3	18.1
Yellow traffic signal trans. (%)	13.6	13.3	15.3
Green traffic signal trans. (%)	11.1	10.1	12.3
ANSI Standard Z80.3 - 1997	yes	yes	yes

Table 2. Optical performance of the sunglass lenses in transmission.

- 5 As shown in Figure 4, where the transmission spectrum of the black-coloured sunglass lens is compared to a hard resin sunglass lens tinted by the traditional liquid dye tinting process, the light absorbing coating has a quite neutral transmission, which provides excellent colour vision.

Table 3 shows the reflectance characteristics of the laminated sunglass lenses. As seen from the wearer-side reflectances, the sunglass lenses are indeed quite anti-reflective of side glare.

TABLE 3

Sunglass lens reflectance	Bronze	Blue	Black
<i>Front side</i>			
Luminous reflectance (%)	8.6	15.8	4.5
CIE coordinate (illuminant C), x	0.36	0.23	0.26
CIE coordinate (illuminant C), y	0.35	0.23	0.24
<i>Wearer side</i>			
Luminous reflectance (%)	0.9	1.0	1.1
CIE coordinate (illuminant C), x	0.30	0.25	0.26
CIE coordinate (illuminant C), y	0.31	0.24	0.29

5 Table 3. Optical performance of the sunglass lenses in reflection.

EXAMPLE 2

In the embodiment of the present invention illustrated in Example 1 (with the light absorbing coating inside the laminate), it is possible to produce semi-visible markings or logos on the sunglass lenses, as shown in Figure 5. By
 10 artificially roughening the surface of the wafer on the interface surface underneath the light absorbing coating (for example by etching the mould from which the internal surface of the front wafer is cast in this case), patterns are created and embedded inside the lens after lamination. The roughened surface is visible from the front of the sunglass lens, because from this side of the light absorbing
 15 coating, the reflectance is non-negligible, so light is scattered from the roughened surface. From the wearer side, because the coating is anti-reflective, reflections from the roughened surface are extremely weak, so that the markings are almost impossible to see. Therefore the logo can even be placed in the optical centre of the lens without disturbing the wearer's vision.

EXAMPLE 3**Light absorbing coating on the outside surface of the front wafer of a laminated lens**

Figure 6 shows another preferred embodiment of the sunglass lens. Again,
5 the front and back lens wafers are hard resin plastic wafers from a commercial
ophthalmic lens system (Sola International Matrix[®] system). The back wafer is
supplied with its external surface pre-coated with a scratch resistant and anti-
reflective coating. The external surface of the front wafer is also treated with a
scratch resistant coating. The internal surfaces of both wafers are of uncoated
10 hard resin.

In this embodiment, the light absorbing coating with asymmetric reflectance
is applied to the outside surface of the front wafer. Neutral attenuation of
transmitted light, an aesthetically pleasing colour when viewed from the front of
the lens and anti-reflection from the wearer-side of the lens again result after the
15 wafers are laminated, as shown in Figures 7 and 8.

Table 4 lists the materials and approximate layer thicknesses used in four differently coloured embodiments of the light absorbing coating. The coatings in this case were deposited using a thin film sputter deposition system.

TABLE 4

Layers			Thickness (nm)			
Number	Material	Primary function	Silver	Gold	Blue	Copper
Substrate						
1	SiO ₂	Scratch resistance	50	50	50	50
2	Nb	Absorption	2	2	2	2
3	SiO ₂	Back AR	80	80	80	80
4	Nb	Absorption	4	4	4	4
5	SiO ₂	Back AR	80	80	65	65
6	Nb	Absorption	4	4	4	4
7	SiO ₂	Back AR	40	40	20	40
8	Nb	Absorption	4	4	4	4
9	SiO ₂	Back AR, front colour		10	40	10
10	Nb ₂ O ₅	Front colour		10	30	30
11	SiO ₂	Front colour	25	30	30	60

- 5 Table 4. Composition of four differently coloured embodiments of the light absorbing coating as deposited on the outside surface of the front lens wafer.

Table 5 shows the optical performance of the sunglass lenses in transmittance.

TABLE 5

Transmission	Silver	Gold	Blue	Copper
Luminous transmittance (%)	13.2	15.8	17.6	21.8
CIE x coordinate (illum. C)	0.33	0.33	0.36	0.33
CIE y coordinate (illum. C)	0.33	0.33	0.36	0.34
Av. UVB transmittance (%)	0.0	0.0	1.0	0.3
Av. UVA transmittance (%)	1.3	1.3	2.2	4.8
Red traffic signal trans. (%)	15.2	18.0	22.3	24.8
Yellow traffic signal trans. (%)	14.0	16.6	19.5	23.0
Green traffic signal trans. (%)	12.7	15.3	16.3	21.1
ANSI Standard Z80.3 - 1997	yes	yes	yes	yes.

Table 5. Optical performance of the sunglass lenses in transmission.

- 5 Table 6 shows the reflectance characteristics of the laminated sunglass lenses. As seen from the wearer-side reflectances, the sunglass lenses are indeed quite anti-reflective of side glare.

TABLE 6

Sunglass lens reflectance	Silver	Gold	Blue	Copper
<i>Front side</i>				
Luminous reflectance (%)	15.4	11.0	17.8	5.6
CIE coordinate (illuminant C), x	0.32	0.35	0.23	0.35
CIE coordinate (illuminant C), y	0.33	0.37	0.23	0.34
<i>Wearer side</i>				
Luminous reflectance (%)	0.98	1.3	1.2	1.8
CIE coordinate (illuminant C), x	0.22	0.23	0.22	0.24
CIE coordinate (illuminant C), y	0.20	0.21	0.25	0.22

Table 6. Optical performance of the sunglass lenses in reflection.

EXAMPLE 4**Light absorbing coating on the outside surface of the back wafer of a laminated lens**

5 In the embodiment the light absorbing coating is deposited on the outside surface of the back wafer as in Figure 9. In this embodiment of the present invention, no additional anti-reflective coating is required to minimise all back reflections to the eye of the wearer, as seen in Figure 11. It will be appreciated that possible reflections from surfaces behind the light absorbing coating do not contribute in any significant manner, because their intensity is severely reduced by
10 the incident light having initially passed through the light absorbing coating. Such reflections are therefore not indicated in the figure.